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Blockchain Technology Impact on Supply Chain Management

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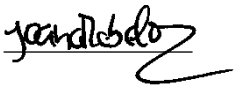
Lisbon, 4th January 2019

Joana Rebelo



Abstract

Constant technological innovation is the current reality for businesses and people. Most of the technologies have great potential beyond what they are designed for. Blockchain, the underlying distributed ledger technology of Bitcoin, has only recently begun to be tested for other uses. This paper studies Blockchain technology and its applications to supply chains. The concept of Blockchain technology will be scrutinized and its implementation benefits and limitations presented. Furthermore, the use cases and benefits of Blockchain technology for supply chains will be analyzed. The paper is complemented with examples and achievements of organizations testing the technology and experts opinions on the technology and its future.

KEYWORDS

Blockchain, Distributed Ledger, Smart Contracts, Supply Chain

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List of Abbreviations & Glossary

PoW	Proof of Work
PoS	Proof of Stake
i2i	island to island, institution to institution, individual to individual
WEF	World Economic Forum
GDP	Gross Domestic Product
SCM	Supply Chain Management
CSCMP	Council of Supply Chain Management Professionals
ROI	Return On Investment
IoT	Internet of Things
IT	Information Technology
Sandbox	Security mechanism to test programs or code in a restricted environment, without harming existing systems.

1. Introduction

1.1 Problem Definition

Modern society is a result of both natural and human-made changes, being technological evolution the fastest and most disruptive of the sort. As a result of this abrupt shift and ever-growing technological dependence, companies and consumers have become truly global, doing business around the world with unknown entities and, otherwise, relying on central agencies to conduct their operations.

Intermediaries are the prevailing solution for safe and secure transactions. With Blockchain technology, this trust is rather achieved through encrypted data, connections and smart code (Tapscott, 2017).

The technology enables trust without trusting, which implies that parties do not have to trust each other, but rather on the system itself. Such trust will be crucial in a digital world.

Supply Chain Management has also come a long way with the aid of technology. Tracking goods and communicating with suppliers has been made easier with the softwares, internet connection and devices that now exist.

However, tracking these goods from production to consumption does not mean that the information added at each point in time is fairly and reliably recorded. With the innovative, although not recent, Blockchain technology, that risk is mitigated.

Blockchain is the underlying technology of the ten-year renowned cryptocurrency Bitcoin. The authors of one of the most popular books regarding Blockchain, “Blockchain Revolution”, began thinking about the technology itself and what other uses it could have beyond cryptocurrencies in 2014, having published the book in 2016 (Tapscott & Tapscott, 2016).

2016 was the year Blockchain technology came out of the Bitcoin shadow. According to Gartner’s Hype Cycle for Emerging Technologies, in this year, Blockchain was, for the first time, placed at the beginning of its “Peak of Inflated Expectations” declaring that its mainstream

adoption would occur in a five to ten year period (Appendix B. 1).

In 2018, the technology was close to this peak's end. The consultancy firm believes that, in the long term, the impact will be certainly positive, but for now businesses are still trying to understand the technology and its benefits (Panetta, 2017).

Investing in Blockchain will play an important role in a company's winning strategy, since achieving trust, transparency and security has never been more prominent (Laukaitis, 2018). As Tapscott & Tapscott (2016) declared, for businesses "It's not Bitcoin, the still speculative asset, that should interest you, […] It's the power and potential of the underlying technological platform" and Harrison *et al*. (2018) stated that "Blockchain will do for business what the internet did for communication".

This work project will develop the aforementioned notions, taking a non-technical approach to Blockchain technology. It is written for managers of several backgrounds, with the goal of deepening their understanding on Blockchain technology for business, its potential, limitations, current and future applications, and implications to supply chains.

1.2 Methodology

The guiding line for this work project will be through a practical approach to Blockchain technology, firstly by describing it, defining its current and future applications (through secondary data), secondly by contextualizing it for supply chain applications (through secondary data), thirdly by conducting in-depth interviews with five professionals of the technology, as a mean to get primary data on the technology's implications, summarizing the findings, opinions and discussion, until, finally, answers to the research questions are achieved and future research introduced.

The secondary data of the work project was collected from technology-related literature, software and platform developers' websites and publications.

Such a technology, being recently studied and with few real application cases, needs to be

carefully searched within the vast sources of information, distinguishing between what has happened and what is going to happen, as most cases are still under development.

The research is in its majority from the last three years, since before 2015 most research was on the cryptocurrency feature and not focused on the technology itself.

Interviews with Blockchain professionals were conducted to get the primary data for this work project. Open-ended interviews are one of the methods of qualitative research (Mohajan, 2018) which allow for accessing data on not so general subjects, providing better insights, gathering different opinions, broadening the perspective and aiding on reaching conclusion.

The work project aims to answer the following research questions in the conclusion chapter**: 1) What is Blockchain technology and where to apply it?; 2) What are the applications, as well as main benefits and limitations, of Blockchain technology for supply chains?**

2. Conceptual Approach

2.1 Blockchain Technology

2.1.1 Definition

Blockchain technology, also known as a Distributed Ledger Technology is, as the name implies, a chain of blocks. Blocks record a transaction, or group of transactions, and are available to all the participants in a network, making Blockchain a peer-to-peer digital ledger (Gupta, 2018).

Participants, otherwise called nodes, have access to an identical real-time updated copy of the ledger and validate the blocks inserted into the chain. Therefore, Blockchain is a distributed database as all nodes have access to the same information (Gupta, 2018).

Cryptography, the process of safeguarding information recorded on the ledger through encoding, is what ensures security in a Blockchain (Gupta, 2018), allowing to store any valuable assets, such as money, stocks, lands, buildings, votes or identities. Tapscott & Tapscott (2016) declare it the “Ledger of Everything”.

One way to look at how Blockchain could be used for business would be to think of it as an

online shared file (Kochar, 2017).

As with Blockchain, an online shared file is both distributed and transparent, considering that on the one hand, once access is granted to the file, every member of the group can view or edit its most recent version and, on the other hand, this same group has access to a list of previous versions regarding every change that occurred and who is responsible for it.

The opposite would be an offline file, where each member has its own version of the file and on every modification the new file would have to be sent to the network's members, restricting them from working on the file at the same time. As a result, there would not be a real-time distribution of information nor transparency.

In transactions between different companies, this offline concept is seen as silo storage (Kochar, 2017), where each participant has its own version of the data, as opposed to a single, shared, distributed and public version, as with Blockchain.

The silo storage can, likewise, be applied to enterprise systems, considering systems for storage and record of information and transactions. Different systems between transacting companies can cause friction in transactions due to the lack of interoperability between systems, leading to errors, such as elimination or duplication of information.

Blockchain is a decentralized way of doing business, independent from a company's enterprise system. Every entity in the network has access to the same copy of the distributed ledger, updated and validated in real time. By excluding unneeded intermediaries and manual cross-validation from systems conflicts, Blockchain technology solves the problem of interoperability, mitigating data errors, as well as reducing time and value spent on correcting them, while automating processes.

2.1.2 Mechanism

The decentralized nature of Blockchain and the automated network validation required to add a block to the chain is achieved through consensus mechanisms. Research shows (Gupta, 2018;

Schumann, 2018; Tapscott & Tapscott, 2016) that the most prominent consensus mechanisms are Proof of Work (PoW) and Proof of Stake (PoS).

In one hand, Proof of Work is consensus attained through work. Several computations have to be made to discover the right hash – a process that is called mining – which will be verified by all the nodes in the network, resulting, if approved, in the addition of a block, with the validated transaction, to the chain (Tapscott & Tapscott, 2016).

PoW is the most viable mechanism to maintain the security of a public Blockchain. To introduce wrong information within PoW, malicious actors would have to gain 51% of all the computational power that exists (Schumann, 2018). Considering this vast amount of power, tampering with information is extremely difficult, expensive and time-consuming to achieve.

On the other hand, Proof of Stake is consensus attained by having a stake of the network. There is no need for mining, the more stake a node has on the Blockchain, the higher chances it has of adding a block to the chain (Schumann, 2018). PoS requires less computational power and it can pose as a more sustainable and less expensive alternative to PoW.

Consensus, agreed by every node upon entering the network, aligned with the chain of blocks' structure, is what makes Blockchain an immutable ledger.

A chain of blocks results from each block being linked to the previous block. Once the block is added to the chain, it is timestamped and a unique identification key, called hash, is given to the block. The block then includes both its hash and the previous block's hash (Gupta, 2018), as we can see below in Figure 1.

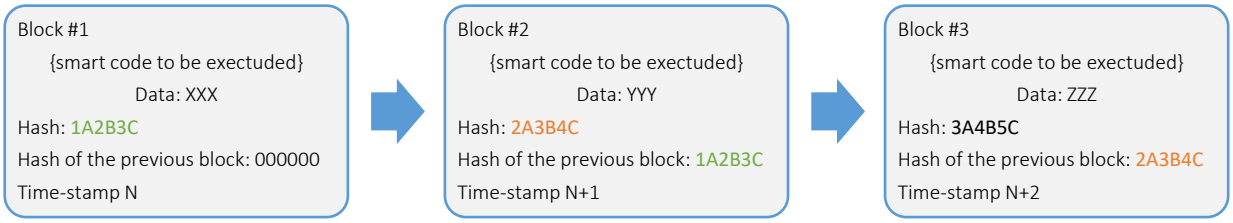

Figure 1: Chain of Blocks
Source: own illustration based on Menting, M. (2018). *How Blockchain is Impacting Industrial Manufacturing and Supply Chain Logistics.* New York: ABI Research.

Tapscott & Tapscott (2016) declare that “The longest chain is generally the safest”. The more blocks there are, the more difficult it is to tamper with the information without being noticed. In every attempt to alter or add information, regardless of the number of changes, a new hash is generated. Consequently, the codes of the changed block, previous and posterior blocks, would have to be rewritten, which would take a lot of time and effort to attain.

2.1.3 Smart contracts

One of the advancements from the Bitcoin Blockchain, implemented by Ethereum, the second greatest public Blockchain, which has great usage and impact for business, is the smart contract capability. Smart contracts can be seen as a digital version of real contracts that are stored on a Blockchain and can execute themselves when certain conditions are met (Gopie, 2018).

Traditional paper contracts have to be certified with the use of an intermediary, such as a notary, and when conditions are not met, complaints have to be made and a process is open, most of the times recurring to lawyers, to verify who is right, taking a long time to solve disputes.

Smart contracts are agreed upon the beginning of business interactions, by all participants in the future transactions, defining what is going to be done in each circumstance. These conditions are digitally recorded and are self-executed, which means that each transaction occurring in the Blockchain is automatically verified in its accordance with the contract. Ergo, the system knows when there is no compliance with the smart contract, emitting alerts, canceling the transaction or performing any other task declared on the contract.

Smart contracts operate in the logical proposition that if or when there is an event, then, automatically, a specific action will take place. As a result, transactions will be faster, more accurate, trustworthy, safer and cheaper to monitor (Gopie, 2018).

2.1.4 Benefits and Limitations

Blockchain technology provides transparency and immutability. Every participant in the network has access to the same copy of the ledger and transactions can be tracked since their

creation. Once in the chain, transactions are encrypted and cannot be tampered without participants noticing. As a result, records in a Blockchain are trustworthy, secure and auditable, reducing friction and increasing accountability (Tapscott & Tapscott, 2016).

Furthermore, Blockchain has a decentralized nature (Harrison *et al.*, 2018), which means that, instead of being controlled by a central organization, Blockchain is governed by all its nodes through consensus mechanisms. Thusly fewer phases are needed to approve transactions, reducing the time it takes to complete one and enhancing efficiency.

Finally, Blockchain has the potential to transform business processes and generate new business models (Tapscott & Tapscott, 2016), through digitization, automation and protection.

Nevertheless, several limitations for Blockchain adoption still subsist.

The greatest constraint of the technology is the amount of power necessary to run it. The two most powerful public Blockchains - Bitcoin and Ethereum - use PoW, which requires massive computational power and, consequently, energy.

According to the "Ethereum and Bitcoin Energy Consumption Indexes" of Digiconomist (2018) (Appendix B. 2 & Appendix B. 3), the 2018 energy consumption of these Blockchains was higher than in countries such as Belgium or Finland. Additionally, 1 Bitcoin transaction consumes around four times more energy than 100 thousand Visa transactions, the traditional payment method. This is both expensive and unsustainable.

As an immature technology, it is still adjusting to the current legal, accounting and tax frameworks (Panetta, 2018), consequently, there is a shortage of skilled and experienced professionals that can execute a smooth implementation of this technology.

Moreover, the association with Bitcoin, a volatile asset, adopted by illicit trade and with lack of scalability (Perez, *et al*., 2018), poses as a threat to Blockchain massification.

Finally, since a Blockchain memorizes every transaction occurred, a considerable amount of storage capacity is needed, which can become costly.

2.1.5 Types of Blockchains

Blockchains can be divided into three types: permissionless, open permissioned and private permissioned (Figure 2). Depending on the purpose intended, organizations will opt for one of these Blockchains.

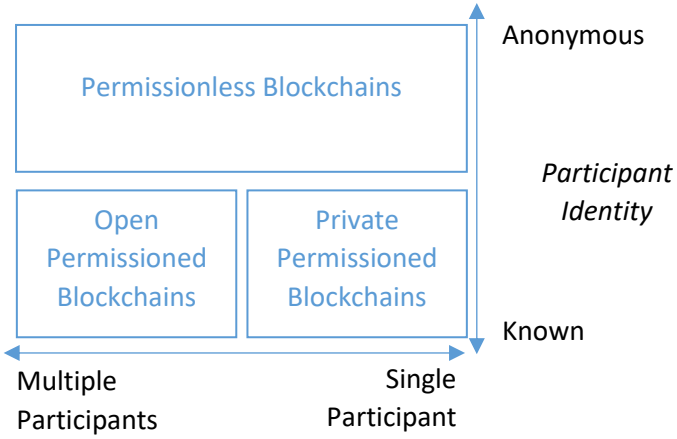

Figure 2: Types of Blockchains
Source: own illustration based on https://www.toptal.com/insights/innovation/blockchain-applications-create-enterprise-solutions

Permissionless Blockchains: Also known as public, these Blockchains are truly decentralized, open and available for anyone who wants to join the network, becoming a participant with the right to access the information shared in the previous and future transactions, as well as performing, recording and validating transactions.

No single organization or authority controls the platform and there are no restrictions. Identities are not revealed in this network nor do a certain identity is needed to access the ledger.

Due to their availability and high reach, these types of Blockchains can be preferred for commercial transactions between unknown or untrusted parties (Panetta, 2017), for businesses looking to benefit from economies of scale (Harrison *et al.*, 2018) and for technology network effects (Tapscott & Tapscott, 2016).

Bitcoin and Ethereum are examples of this type of Blockchains.

Permissioned Blockchains: These Blockchains operate between a limited number of identified participants. The participants are known through authentication mechanisms, which means that the network does not necessarily have access to their names, addresses or backgrounds, rather

it knows they are valid, not anonymous, users who can be accountable for their actions.

Such Blockchain is the most relevant for enterprises since it does not deal with an infinite number of parties (Patel, s.d.) and different categories of users can be provided different levels of access (Gupta, 2018). These capabilities promote confidentiality, security and competitiveness. However, a closed network is more vulnerable to attacks. With fewer participants and blocks recorded, tampering with the information recorded is not as difficult as in public Blockchains (Tapscott & Tapscott, 2016).

Permissioned Blockchains can either be open or private:

- Open Permissioned: Also known as semi-private or consortium, these Blockchains are controlled by a group of participants with similar goals who mainly want to set some standards for the use of Blockchain technology. These Blockchains operate between several organizations and they can be the preferred ones for business's transactions (Patel, s.d.). The following are examples of this type of Blockchains, mainly focused on open source to solve industry-specific business problems:
    - Hyperledger is an organization that allows companies from various industries to access Blockchain technology, by connecting them to open source code for several applications and worldwide developers; As of September 2018, Hyperledger has 270 members worldwide (Hyperledger, 2018)
    - Enterprise Ethereum Alliance, with nearly 300 members, is focused on developing open source standards for the use of Ethereum within enterprises (Enterprise Ethereum Alliance, 2018);
    - R3 is an "enterprise Blockchain software firm with more than 200 members across multiple industries", responsible for the launch in 2016 of an open source Blockchain platform called Corda (R3, 2018).

- Private Permissioned: In these Blockchains, only some participants are allowed through an invitation from a central organization which controls the platform, restricting access to trusted parties (The Economist, 2018). Due to its centralized nature, these types of Blockchains operate within organizations and can become similar to a current database system. Companies can use these Blockchains for security, efficiency and auditability.

  A company's internal Blockchain can be an example of this type of Blockchain.

2.2 Current Applications

2.2.1 Bitcoin and Ethereum

Blockchain's most popular and successful applications are cryptocurrencies. The first and, still, most valuable of them is Bitcoin, representing more than 50% ($66,45 billions) of the cryptocurrencies market, according to Coin Dance (2018) (Appendix B. 4).

Bitcoin is the public Blockchain responsible for the first virtual currency, developed in 2008 by the pseudonym Satoshi Nakamoto. This currency, issued within a decentralized, peer-to-peer network, without any control or intervention from financial institutions (Bitcoin, 2008), posed as an alternative to traditional currencies issued by central authorities. This capability reduced the cost of transactions and responded to the absence of trust in the financial sector.

The second most valuable digital currency is Ether, from the Ethereum public Blockchain, created in 2013 by Vitalik Buterin and launched as a platform in 2015 (Ethereum Foundation, s.d.). Unlike Bitcoin, Ether was not meant to solely be a payment method, rather it was a way for developers to build applications that took advantage of the distributed ledger technology. Through a peer-to-peer network, developers could use the platform to share their code and knowledge with the network participants.

Ethereum most innovative characteristic was its programmability. Therefore, the Ethereum platform and its programming language, both run on Blockchain technology, could ascend to

more complex operations beyond cryptocurrencies, which could then be defined and agreed upon in a smart contract (Wüst & Gervais, 2018).

2.2.2 ConsenSys

ConsenSys, a company built on the benefits of Blockchain and the power of decentralized applications for businesses and governments across the world, is working within the Ethereum network and expanding the Blockchain technology possibilities.

This 2015 consulting firm develops, tests, educates, creates business, financial and legal solutions and cares about the social impact of a decentralized future (ConsenSys, 2018).

One of ConsenSys's solutions is Kaleido, the result of a partnership between ConsenSys and Amazon Web Services (AWS)**.** Kaleido develops innovative Blockchain solutions by running on AWS, which defines itself as "the largest global infrastructure for building end-to-end Blockchain platforms, cost-efficiently and at scale" (AWS, s.d.).

Kaleido is a Blockchain Business Cloud and Software as a Service (SaaS) platform to assist enterprises in conducting their businesses through permissioned Blockchain networks, without the need to develop a Blockchain solution by themselves. Its layout and operating simplicity allow any enterprise to use Blockchain technology for improving its performance, security, globalization and scalability (Kaleido, s.d.).

One of the projects of Kaleido is "Project i2i**"** with the UnionBank of the Philippines (UBP). This project aims to increase inclusiveness in banking services. In the Philippines, millions of people in rural areas do not have proper access to banks, as rural banks have limited electronic resources and connectivity. Simple transactions, such as payments, are difficult to execute.

The solution aims to bring closer the rural population to the banking network, by connecting rural and national banks through a Blockchain network (Appendix B. 5). Transactions can, this way, be faster, cheaper and more efficient. Though in pilot phase, the platform is expected to launch in the first quarter of 2019 with 80 rural banks (ConsenSys Solutions, 2018).

As of September 2018, the UBP is also part of J.P. Morgan Interbank Information Network, a "live application of Blockchain technology" to accelerate the payments processes as well as cross-border transactions (J.P. Morgan, 2018).

2.2.3 LO3 Energy

The energy sector has also been a target of Blockchain technology. As a centralized sector, with few energy suppliers per country, consumers do not have bargaining power over this necessary utility nor knowledge of its origin. Companies, such as LO3 Energy, have aligned with Blockchain technology to overcome this dependency, by decentralizing energy production.

LO3 Energy uses Blockchain technology to enable energy to be produced, stored, purchased, traded and used, all at a local level. To achieve its goal, LO3 Energy has developed Exergy, a Blockchain permissioned data platform that connects local consumers and producers, allowing them to trade energy across existing energy infrastructure (LO3 Energy, s.d.).

The company states that local producers are "prosumers" since they are both producers and consumers of energy. A local building with solar panels installed is an example of a prosumer. The company allows for the energy produced and not consumed by these local prosumers to be traded with local consumers, who are not able to produce sufficient energy for their own consumption. Thusly the energy is traded locally, reducing energy waste by not having to recur to a central energy supplier located at a long distance.

Central energy suppliers themselves can, likewise, benefit from this platform. By having access to a peer-to-peer network of producers and consumers, connected through devices that share energy consumption data, energy suppliers can respond more efficiently to energy demand.

The company's first project was the Brooklyn Microgrid Project, launched in 2016. After this successful project, other pilot projects were placed in Texas (USA), Enexa (Australia), Allgau (Germany) and Cornwall (UK).

LO3 Energy was created in 2012 and in 2016 made the first energy Blockchain transaction in

the world. In 2017 Exergy was launched and for 2019 the company is expecting to release a major mobile application (Exergy, 2018). LO3 Energy's ultimate goal is to develop sustainable communities through an energy online marketplace.

2.2.4 Additional Applications

VeChainThor, platform with the purpose of reducing the carbon footprint (VeChain Foundation, 2018); Portuguese Association of Blockchain and Cryptocurrencies, which represents the Blockchain Portuguese community (Antunes, s.d.); TrueTickets, platform to avoid ticket frauds and inflated resale prices (True Tickets, s.d.); uPort, platform to control personal digital identities (uPort, s.d.); Estonian E-Health Foundation, making Estonia the "first country to use blockchain for healthcare on a national scale" (Einaste, 2018). See Appendix C.

2.3 Future of Blockchain Technology

In 2015, the WEF conducted the "Technological Tipping Points" survey of 816 "executives and experts from the information and communications technology sector" (WEF, 2015), which, for Blockchain technology, resulted in two main shifts: governments and digital currencies.

The first one is expected to occur by 2023, with a government using Blockchain to collect taxes for the first time, whereas the second one is expected to occur by 2027, predicting that Blockchain technology will store 10% of global GDP.

The survey also computed the percentage of respondents that expected these tipping points to occur by 2025, being 73% and 58% respectively.

Research shows that the rising awareness of Blockchain technology has created a powerful incentive for the development of Blockchain solutions. Several sectors are opening up to the potential of this technology, such as banking, healthcare, supply chain, public sector and utilities (SAP, s.d.).

However, as occurs at the starting stages of technological trends, most of the projects are still in pilot phase and the real accomplishments and social implications are yet to be discovered.

According to Gartner's Hype Cycle for Emerging Technologies (Appendix B. 1), the following five to ten years are going to be crucial for the integration and standardization of the technology. Companies and governments have to come together for policy-making and education.

3. Blockchain Technology for Supply Chain

3.1 Context

Supply Chain Management (SCM) overviews the activities and processes that transform raw materials into products available for consumption. SCM is responsible for providing quality trusted products and services with efficiency and customer centricity (CSCMP, s.d.).

The management of a supply chain is a complex business process, involving different types of organizations, channels and regulations. Its purpose goes beyond moving a product or material, it also involves flows of value, information and services (CSCMP, s.d.) to deliver the right product to the right customer and anticipate the customer's needs.

An effective SCM can bring benefits to every participant in the chain, reducing uncertainty and risks through coordination. Each party has a particular role, yet together they cooperate towards a common goal (CSCMP, s.d.).

Additionally, SCM can lead to an increase in profitability and competitiveness. Firstly, costs are reduced through improvements in inventory levels and cycle time. Secondly, satisfaction is raised due to superior product availability and personalization (Fawcett *et al.*, 2008). Nonetheless, achieving these benefits has challenges. Misaligned goals and lack of trust lead to competition, instead of cooperation. Additionally, difficulties of interoperability between different enterprise systems can delay the delivery time (Fawcett *et al*., 2008).

According to "The 7 Principles of Supply Chain Management" (Anderson, Britt, & Favre, 2007), one of the principles of SCM is to "develop a supply chain-wide technology strategy that supports multiple levels of decision making and gives a clear view of the flow of products, services, and information". Ten years ago, this strategy was about combining engineering

processes with information technology through enterprise systems. Today, it is about integrating innovative technologies, such as Blockchain, into the supply chain, intelligently tracking and sharing information between all steps of the process.

3.2 Use Cases

Blockchain has the power of connecting every supplier in a supply chain (Figure 3), providing them with transparency over what is happening at every stage of the process. This is possible due to Blockchain's decentralized nature and distributed ledger. This shared transactions' record with no central authority, combined with smart contracts and fewer intermediaries, reduces process cycle time, costs and conflicts (Gupta, 2018).

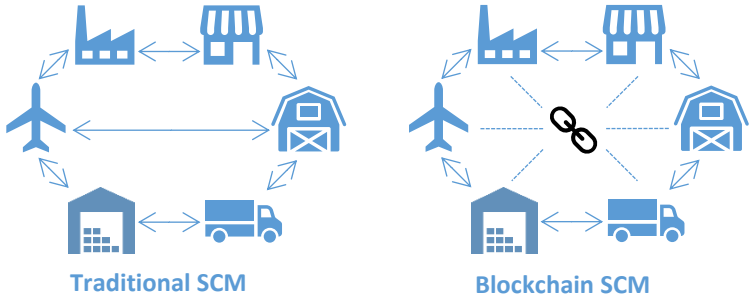

Figure 3: Traditional SCM compared to Blockchain powered SCM
Source: own illustration based on Wüst, K., & Gervais, A. (2018). Do you need a Blockchain? *2018 Crypto Valley Conference on Blockchain Technology (CVCBT)*, (p. 45.54). Zug, Switzerland

One of the most important Blockchain's uses for supply chain is provenance, which means the ability to track a product from farm to consumption (Gupta, 2018). At every supply chain's transaction, a time-stamped immutable record is generated containing a product's condition, location and ownership at that specific moment in time (Appendix B. 6).

As an example, if a product is manufactured and shipped in China, the record will state China as the product's original location. It will not be possible to change this location to France. Blockchain keeps track of all changes and additions to the ledger, every product and movement have a unique identification key. Therefore, such an attempt to change the location would be seen by everyone involved in the supply chain. Moreover, every supplier would have to approve this change in order for it to be added to the Blockchain.

Furthermore, there are several parties in a supply chain, each of them having access to the products at a certain stage of the chain. The end party of the chain – consumers – as well as most of the suppliers in the middle, do not have clear visibility over the whole operation and product's history, that is, over its origin, ownership, legitimacy, authentication, certification and quality, which can be achieved with Blockchain (Menting, 2018).

Blockchain's provenance and visibility combined increase transparency and product safety in the supply chain, enhancing auditability, accountability and traceability of products, services and data, as well as, preventing errors and frauds from counterfeit (Tapscott & Tapscott, 2016).

In addition, Blockchain allows for more effective inventory management, through asset tracking and smart contracts. Certain actions can be set towards predefined inventory levels, putting in motion orders, payments, replacements, distribution and deliveries when needed. Such smart inventory management enables on-demand manufacturing, reducing the risk to excess or scarce inventory towards demand levels (Menting, 2018), as well as efficiently dealing with recalls and returns.

Besides inventory management, Blockchain can also aid in machine and process maintenance. Several devices connected through a production line, sharing status information between each other and controlled through smart contracts, instead of a central entity, can automate orders related to maintenance, preventing machinery malfunctioning and process delays (Menting, 2018). Process maintenance aligned with efficient inventory management leads to more profitable processes and, consequently, increases ROI (SAP, n.d.).

Moreover, Blockchain is also beneficial for international trade. Trust can be difficult to achieve in cross-border transactions that resort to unknown suppliers with their own national specific systems. As a distributed ledger technology, where different participants have an equal copy of the transactions and consensus is achieved within the community, Blockchain allows for a faster and transparent distribution of products around the world (Gupta, 2018).

Finally, Blockchain can also achieve digitization of paperwork (Menting, 2018). Every document needed for a transaction can be stored in the distributed ledger. Digital documents promote efficiency and are more securely, faster and less costly traded within cross-border transactions, reducing friction and improving automation.

3.3 Benefits and Limitations

The benefits and limitations of Blockchain technology mentioned in chapter 2 can also be extended to SCM.

Furthermore, the aforementioned provenance, visibility, inventory management, international trade and digitization use cases, can, likewise, be considered as Blockchain's benefits for SCM. Blockchain provides visibility across different levels of suppliers and production phases, hence, if there is intermediary products' demand fluctuation, the middle suppliers' movements can be predicted to avoid a negative impact over production levels of finished goods and decrease the risk of supply chain volatility (Sissman & Sharma, 2018). Consumers and other participants in the supply chain have real-time updates to production, such as the change of suppliers, understanding possible variations on prices and quality (Sissman & Sharma, 2018).

Blockchain provides verification of investment policies and products' label data, such as origin, certified ways of production and practices. This results in the certainty that the company, suppliers, consumers and investors have their values aligned (Sissman & Sharma, 2018).

Nevertheless, several constraints for Blockchain use in SCM still subsist.

Every participant in a Blockchain network has access to the whole supply chain's processes and strategies. As so, privacy measures need to be created, such as assigning specific participants with access to classified information, otherwise, competitors could gain access to confidential information, such as strategic suppliers and trade deals, reducing a company's competitive advantage and allowing producers to learn about the intermediate suppliers contracted and cut them out of the supply chain (Gupta, 2018).

Moreover, everything is recorded on the Blockchain's public ledger, which means that if some business partner adds illicit data on the ledger, such as "personally identifiable information, protected health information or classified information", the rest of the participants can wind up being guilty by association, since records cannot be tampered with or deleted from Blockchain (Sissman & Sharma, 2018).

As previously mentioned, in a public Blockchain network is extremely difficult to gain 51% of computational power. However, a Blockchain used for a company's supply chain would not be entirely public, as no enterprise intends to disclose all information of its business to the public. A permissioned Blockchain, with a finite number of partners, would be the one to use. As so, such a Blockchain would be easier for some organization to gain control over 51% of the processing power for generating new blocks, which means having the power to decide what is true and to attack the Blockchain, posing as a significant threat (Sissman & Sharma, 2018).

3.4 Organizational Examples

3.4.1 Everledger

In 2015, Leanne Kemp founded Everledger in London. This start-up is committed to using Blockchain technology and IoT to track provenance and ownership of precious assets, from their origin to consumption (Perez, *et al.*, 2018), with the aim of delivering "a positive social, economic and environmental impact" (Everledger, s.d.).

The company is most known for its first assets tracked – diamonds. It tracked diamonds from pure form, in the mine, to jewelry. Everledger's goals were to distinguish between fair trade, conflict-free area diamonds and conflicting war zones diamonds used to finance illicit or violent activities (Perez, *et al.*, 2018), also known as *blood diamonds,* as well as distinguish between authentic and counterfeit diamonds.

Everledger describes that, for each diamond, at every stage of the supply chain, a high-resolution photo of the diamond status is recorded on the Blockchain ledger, alongside

certificates of authenticity, payments and product details, all in real time (Everledger, s.d.). Records are, therefore, completely auditable and immutable.

Everledger holds permanent records of over 1 million diamonds in its Blockchain-enabled platform, an open permissioned Blockchain platform (Wüst & Gervais, 2018).

After its proven success in tracking diamonds, Everledger expanded to provide transparency for other high-value assets: gemstones, minerals, fine wines, luxury goods, fine art and insurance (Everledger, s.d.).

Everledger combines its Blockchain platform with strategic industry partnerships, providing unique digital identities to physical assets and enabling a digital record of "proof of authenticity, existence as well as ownership". As a result, it creates an "ecosystem of trust" within a global supply chain and between various stakeholders, providing transparency in information related to provenance, tracking and certification (Everledger, s.d.).

3.4.2 Walmart and IBM Food Trust

Blockchain can be a strong player in food safety solutions. For this reason, Walmart, a multinational retailer, has partnered with IBM, a multinational IT company, to help improve food safety, freshness and quality, reduce waste and ensure sustainability (IBM, 2018).

IBM has a great presence in Blockchain technology, having used the Hyperledger open source software to build its own IBM Blockchain platform. One of Blockchain's solutions built on IBM Blockchain platform and emerged from expertise in both technology and industry was the "IBM Food Trust" (IBM, s.d.).

On October 8th, 2018, IBM Food Trust became "generally available after 18 months in testing, during which millions of individual food products have been tracked by retailers and suppliers" (IBM News Room, 2018).

The solution connects "growers, processors, wholesalers, distributors, manufacturers, retailers" and other stakeholders in each step of the food supply chain (Appendix B. 7), recording every

information and certification, from product characteristics to product status, to safely trace food from origin to consumption, enhancing end-to-end visibility and accountability (Gupta, 2018). The information shared within the Blockchain is possible due to the various IoT devices, connected throughout the supply chain, providing information into the ledger. Such examples of devices are temperature sensors inside shipped containers, recording temperatures at each point in time. Combined with smart contracts, temperatures outside defined parameters can result in alerts or automated return of the products, keeping perishable products fresh, reducing waste and ensuring safety for consumption (Laukaitis, 2018).

Furthermore, recalls due to contamination or safety issues are also faster and more efficient with Blockchain technology. Retailers can track where the product is from, when and where it was shipped, determining the cause and effect of the issue, allowing to rapidly substitute these products from stores and avoiding further risks to consumers' health (Laukaitis, 2018). In fact, all this tracking research can take only 2.2 seconds, instead of the current 7 days (Smith, 2018). On 2017's Christmas time, turkeys from a Walmart supplier could be traced using the code printed in the turkey label, into the website or via text message, to discover the family farm's history of where the turkey originated (Otto, 2017).

In 2017 Walmart "conducted successful pilots using Blockchain to track mangos and pork" and, in 2018, Walmart established partnerships with food suppliers to expand Blockchain's use (McMillon, 2018). Moreover, in response to an outbreak of E. coli in romaine lettuce, Walmart is asking suppliers of fresh, leafy greens, to use Blockchain technology to trace products from farm to store. Their systems are expected to be in place by September 2019 (Smith, 2018).

3.4.3 TradeLens

Blockchain can be a strong player in logistics solutions. For this reason, Maersk, an "integrated container logistics company and global leader in shipping services" (Maersk, s.d.), has also partnered with IBM Blockchain solution for transparency within global trade.

On January 2018, the companies announced the joint venture for the world's first global trade digitization platform aimed at the international shipments' community. This platform, TradeLens, was only announced on August 2018, with 94 participants, ranging between port and terminal operators, global container carriers, customs authorities and brokers, freight forwarders, transportation and logistics companies (Maersk, 2018).

TradeLens promotes efficiency, predictability and security for information exchanged, fostering trust among the global supply chain by sharing real-time end-to-end supply chain information, transferring trade documents across organizations and improving asset management (TradeLens, s.d.).

Shipping documents and data, such as temperature and weight provided by IoT devices, recorded in the Blockchain and combined with smart contracts, result in efficient digital collaboration between several international parties, providing a secure and immutable audit trail (Maersk, 2018).

Without limitations, such as documentation errors or information delays, and provided with better visibility and communication, shipment transit time can be reduced up to 40%, costs can be reduced by thousands of dollars and steps taken to track shipments and products' conditions can be reduced from ten steps to one step and five people to one person (Maersk, 2018).

More than 247 million shipping events have been captured on the platform (TradeLens, s.d.) and the growth rate is close to one million events per day. Events include data such as arrival times and documents such as commercial invoices (Maersk, 2018).

TradeLens was expected to be fully commercially available by the end of 2018 (Maersk, 2018). However, failure to partner with other global shippers has stalled this expectation. As Maersk conjointly owns the platform and its intellectual property, rivals do not believe in a fair share of profits (Tinianow, 2018). TradeLens should converge into a more equitable business model.

3.5 Experts' Interviews

For a further assessment of Blockchain technology's impacts on businesses and supply chains, several Blockchain professionals were interviewed (Appendix A).

The findings focused on the potentials and constraints of Blockchain for supply chain, companies' implementation of Blockchain, regulations and policies, time for adoption or massification and the future of Blockchain, summarized in Table 1 and Chapter 3.6.

Table 1: Summary of Experts Interviews

	E1	E2	E3	E4	E5	Avg
Impact on business						
Impact on interactions						
Early notice, beyond cryptocurrencies						
Revolution and redesign of supply chains						
Solution for data reliability problems						
Every company should implement Blockchain						
Create new regulation						
Failure of prototypes due to Blockchain complexity						

*E refers to expert; Avg refers to average; Symbols represent intensity of the experts' answers on each aspect, between strongly disagree, disagree, slightly agree, agree and strongly agree.
Source: own table based on experts' interviews

Blockchain technology's potential beyond cryptocurrencies was recognized immediately upon researching and learning about it by the experts in development and advisory, whereas for the rest of the experts it was when Ethereum first appeared and, with it, smart contracts and programmability.

All experts agreed that Blockchain will do for businesses and transactions what the Internet did for information and communication (Gupta, 2018), with the developer and PhD student adding that Blockchain will allow for a secure exchange of value over the internet, the enterprise systems' expert adding it will become a global transactional platform and solutions' experts claiming it will create the Internet of agreement, with smart contracts enforcing agreed upon conditions between unknown parties, changing how humans and businesses interact.

There was also unanimity on the potential of Blockchain technology for supply chains, being,

for the solutions' experts, one of the most interesting use cases for the technology, providing the ability to track a product in real time and record it in an immutable ledger, preventing liabilities from frauds and increasing trust for consumers. For the PhD student, the result is not a new supply chain, rather an optimized one, more efficient for time and costs.

Moreover, for solutions' experts, supply chains involve great amounts of classified data that can be expensive to store and process, hence, scalable, fast, privacy concerned and affordable solutions are needed, along with openness and business readiness to implement these changes.

According to these professionals, it is important to note that Blockchain will not immediately benefit every company or process. Each case has to be thoroughly analyzed, regarding possible Blockchain implementations and trade-offs from current systems. Nevertheless, as the enterprise systems' and solutions' experts declared, companies should not refrain from exploring how some processes would look under Blockchain since, at some point, all companies are expected to have a connection to a Blockchain network.

There is lack of Blockchain standard solutions, thus, according to the developer and PhD student, for the same problem, different solution providers will have completely different approaches. The developer and the enterprise systems' expert also mentioned that, solution creators need to know what the technology enables and coordinate with potential participants for a general benefit and promotion of decentralization.

Finally, according to the development expert, Blockchain will not solve existing problems such as data reliability. Blockchain's consensus mechanism works for protocols validation, not for data validation. The solutions' experts declared that the veracity of the information stored on blocks is a job for the network participants to agree on.

3.6 Future of Blockchain for Supply Chain

In-depth interviews also focused on the future of Blockchain, regarding governments and timeframe. Experts in development and advisory agreed on the dilemma between assuring

innovation and protecting the final consumer, as innovation always causes apprehension.

Governments need to encourage innovation. The demand is not for new regulations, rather adjusting the existing ones to a new reality, defended the PhD student. According to the latter and the advisor, until regulators truly understand Blockchain, policies will not facilitate its adoption.

Furthermore, policies should refer to the use case and application level, instead of the technology protocol level, defended one solution's expert. The digital representations of physical assets, also known as tokens (Harrison *et al.*, 2018), need to be characterized and assigned specific laws, which can take time the technology does not have, according to the developer. In the meantime, the advisor claimed the proper approach to Blockchain could be through pilot programs and regulatory sandboxes for new projects and developments.

Regarding how long it will take for Blockchain to be generally applied, experts are uncertain of the time to adoption but agreed on the timeframe between three to five years. Until there, advancements will mostly be on clarification, exploration, first movers and tests.

Nonetheless, experts are certain of the technology's potential to greatly impact society. Without central authorities controlling value and information on Blockchain, access is granted for everyone and everywhere, giving power back to people.

Research shows that, the digitalization of supply chains will be reached through a combination of Blockchain and several emerging technologies (Perez, *et al.*, 2018).

As Perez, *et al.* (2018) predict, a smart supply chain will be both a competitive edge and necessity. Companies that refuse to innovate, will experience competition from their own Blockchain version.

4. Conclusion

A practical and simplified approach to Blockchain technology and its applications to supply chains were the goals of this paper. Despite not being a recent technology, Blockchain has just

recently started to feature as innovative. For now, its full potential is still underestimated, its real applications short and massification is long from happening.

Blockchain technology is a peer-to-peer digital ledger, connecting different participants of a network. The distributed ledger technology provides the participants with an identical real-time updated copy of the ledger, composed by chronologically approved blocks of transactions. Participants are responsible for this approval, achieved through consensus mechanisms.

Cryptocurrencies are Blockchain most known application, however, several industries are opening up to the potential of this technology, which allows for worldwide partnerships and value generation.

Through an internet connected device, Blockchain technology grants trust, transparency, immutability, accountability, decentralization, security and efficiency.

Blockchain technology's application in supply chains will result from connecting different suppliers and consumers. Products' provenance, end-to-end visibility, transparency, inventory management and globalization will transform suppliers and consumers' knowledge of products, increasing safety and preventing frauds. Blockchain will benefit the digitalization of supply chains and it will create more profitable processes.

Future research can focus on overcoming Blockchain's implementation challenges on storage capacity, latency, scalability, privacy, security, interoperability, energy consumption and costs.

Companies and governments need to truly understand the technology and coordinate with potential participants through decentralized solutions, leading to winning strategies, policies and general benefit.

More importantly, society and businesses need to embrace innovation and change.

Blockchain will become the best innovation for businesses after the internet, empowering businesses and people all around the world.

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Appendices

List of Appendices

Appendix A: Experts' Interviews

The appendix shows a summary of the interviews' questions.

The interviewees were professionals with Blockchain expertise from companies working with this technology. These companies help their clients implement Blockchain technology in their operations by creating tailored solutions, providing investment and advisory.

The experts ranged between solutions' specialists, developer, Blockchain's PhD Student and enterprise systems' expert who is also a Professor from Nova Information Management School.

Questions:

1) How did you become professionally/personally involved with Blockchain technology?
2) Blockchain will do for business/transactions what the internet did for communication/information. What is your opinion on this statement?
3) When did you realize Blockchain technology had potential beyond cryptocurrencies?
4) Do you believe Blockchain will revolutionize a company's Supply Chain?
5) Blockchain provides an immutable ledger based on the concept that what goes into a block after validation is the truth, but how can it prevent the information inserted from being false? How can it know if the first block ever added on the chain, and, therefore, all the sequential blocks, was accurate?
6) From your perspective, what are the main limitations/challenges of Blockchain technology for businesses? How can companies surpass them?

7) When should a company implement Blockchain technology (having in mind the current systems companies use)

8) Should all companies implement Blockchain?

9) How should governments adjust policies to enhance the use of Blockchain technology?

10) Most of the current Blockchain for business examples are prototypes not tested yet. What do you think can prevent some of those examples from being successful?

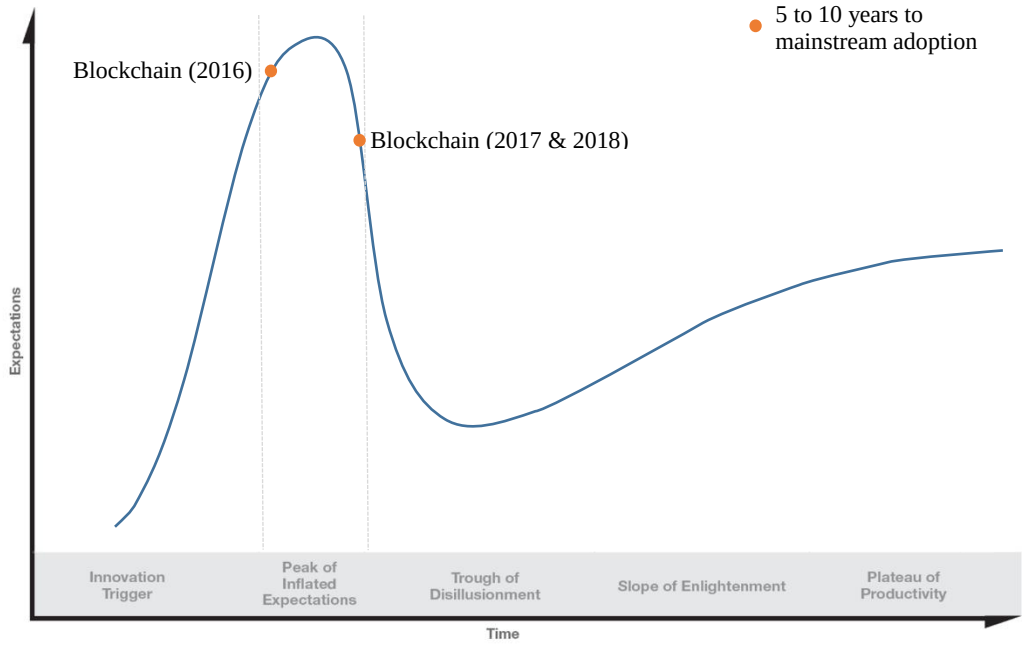
11) How long do you think will take for companies to integrate blockchain in their supply chains: 1-3years; 3-5years; 5-7years; 7-9years; +10years?

12) How do you think Blockchain will affect the redesign of supply chains?

13) What do you think is the future for Blockchain?

Appendix B: Figures

Appendix B. 1: Evolution of Gartner's Hype Cycle for Emerging Technologies from 2016 to 2018



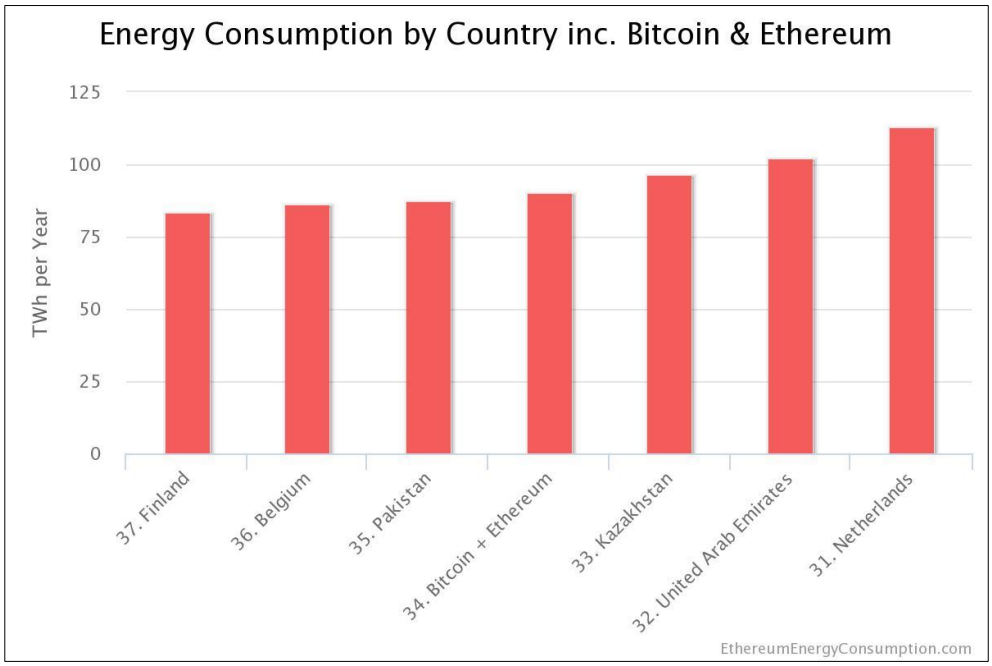
Source: own illustration based on:

2016: https://www.gartner.com/newsroom/id/3412017

2017: Panetta, K. (2017). Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017. Retrieved October 26, 2018, from https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/

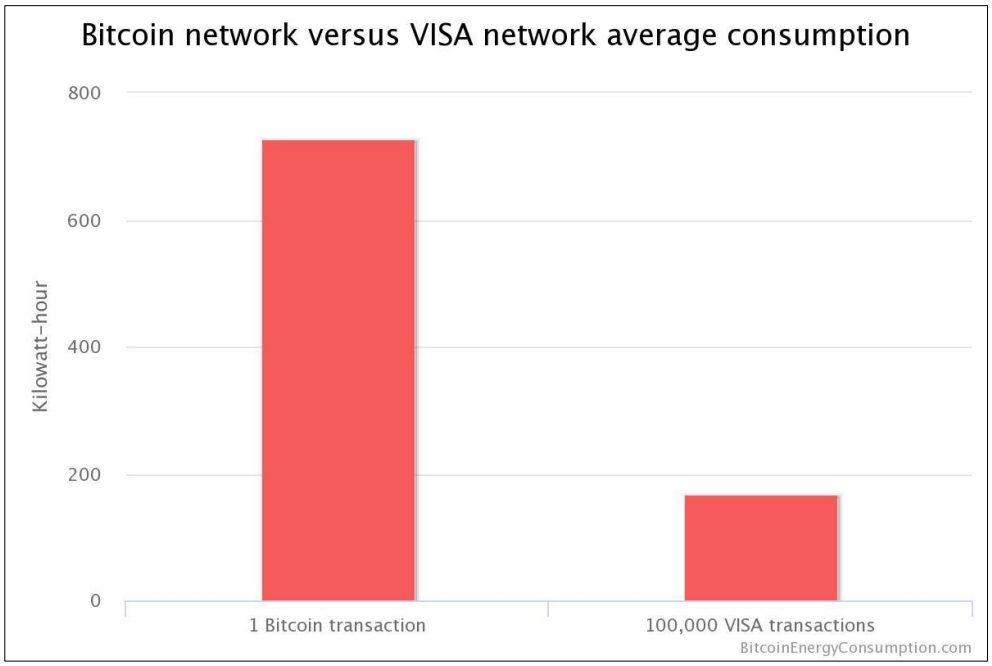
2018: https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/

Appendix B. 2: 2018 Energy Consumption by Country, including Bitcoin and Ethereum



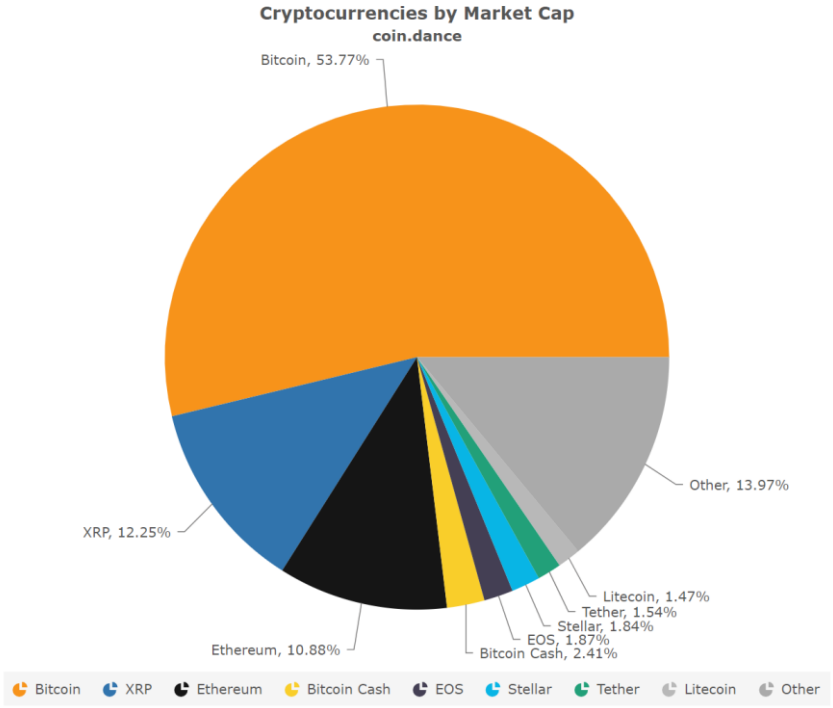
Source: Digiconomist. (2018). *Ethereum Energy Consumption Index*. Retrieved November 15, 2018, from https://digiconomist.net/ethereum-energy-consumption

Appendix B. 3: 2018 Bitcoin network versus VISA network average consumption



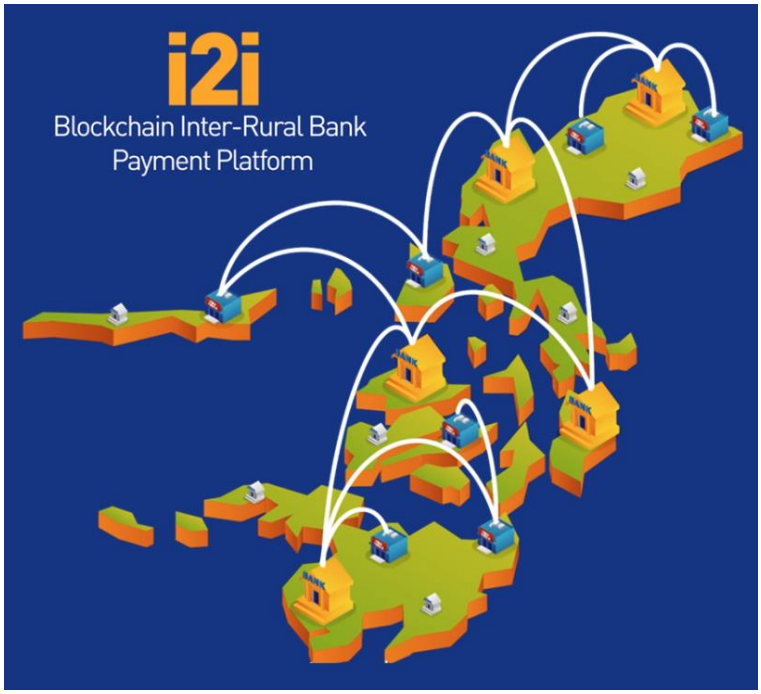
Source: Digiconomist. (2018). *Bitcoin Energy Consumption Index*. Retrieved November 15, 2018, from https://digiconomist.net/bitcoin-energy-consumption

Appendix B. 4: Cryptocurrencies by Market Capitalization on 27th December 2018



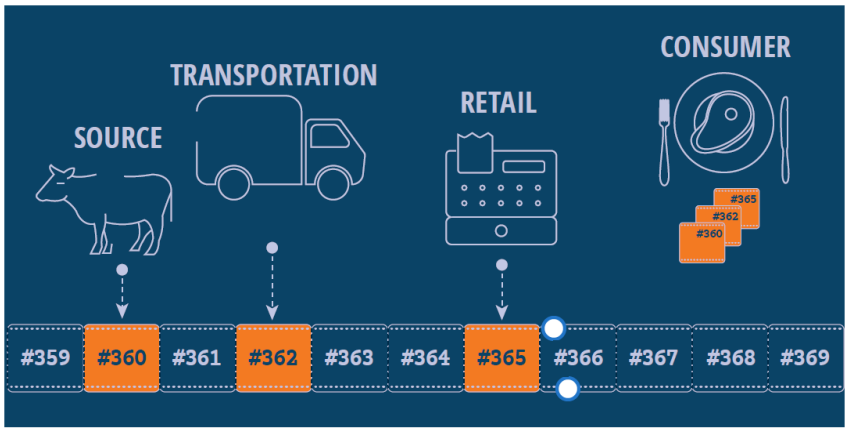
Source: Coin Dance. (2018). *Cryptocurrencies by Market Cap Summary*. Retrieved December 27, 2018, from https://coin.dance/stats/marketcaptoday

Appendix B. 5: Project i2i, connecting national and rural banks of the Philippines



Source: https://media.consensys.net/project-i2i-an-ethereum-payment-network-driving-financial-inclusion-in-the-philippines-233e5eda135e

Appendix B. 6: Unique identification keys from farm to table



Source: Menting, M. (2018). *How Blockchain is Impacting Industrial Manufacturing and Supply Chain Logistics.* New York: ABI Research.

Appendix B. 7: Walmart Blockchain Supply Chain

Source: McMillon, D. (2018). *Striving to be the Most Trusted Retailer: 2018 Update on Walmart's Global Ethics & Compliance Program*. Retrieved December 3, 2018, from https://corporate.walmart.com/global-responsibility/global-compliance-program-report-on-fiscal-year-2018

Appendix C: Additional Blockchain Applications further explanation

VeChainThor: public Blockchain platform developed by VeChain, a 2015 Singapore based company for "real-world applications using public Blockchain technology", BYD, Chinese and world's largest electric cars and batteries manufacturer, and DNV GL, a "global quality assurance and risk management" Norwegian company (VeChain Foundation, 2018).

The companies partnered in 2018 to develop a carbon banking solution for electric cars, collecting usage data from millions of vehicles onto VeChainThor public Blockchain platform. Drivers will receive carbon credits "based on their vehicles' driving performance and carbon reduction" that can then be exchanged by products and services provided by other companies in the carbon banking network. (VeChain Foundation, 2018);

Portuguese Association of Blockchain and Cryptocurrencies: combating scam schemes, promoting the technology, collaborating with legislative actors and encouraging the adoption of Blockchain in companies (Antunes, s.d.);

TrueTickets: platform developed on IBM Blockchain that tracks a ticket from origin to event and lets the artist control tickets' price cap (True Tickets, s.d.);

uPort: platform developed with Consensys to protect a person's identity: "allows users to register their own identity on Ethereum, send and request credentials, sign transactions, and securely manage keys & data" (uPort, s.d.);

Estonia: Securing patient's electronic health records and storing related activity logs, to promote privacy and integrity of health records (Einaste, 2018).